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1.0 INTRODUCTION

1.1 The purpose of the Failure Modes and Effects Analysis (FMEA) is to discover critical failure areas in a system and to remove susceptibility to such failures. Each possibility of failure is considered in light of its probability of occurrence and its effect on mission success. Corrective action may then be recommended for the critical failure areas.

1.2 This memo contains the results of the final FMEA for the 300 Array LRRR experiment. This analysis has been revised and is now reissued as the final revision.

2.0 SUMMARY

2.1 Since an LRRR was successfully deployed on the moon as a part of the Apollo 11 mission, this FMEA will not dwell in the aspects of the Apollo 15 LRRR which are identical to those of Apollo 11, the retroreflector and the retroreflector~mounting hardware. The primary areas of interest are the redesigned supporting structure, the addition of side panel Array B, and the consequent change in method of deployment.

2.2 For historical reference and comparison prior Failure Modes and Effects Analyses are as follows:

(1) EASEP, Apollo 11, EATM-25, 10 January 1969.

(2) ALSEP, Apollo 14, ATM 868A, 20 August 1970.

(3) ALSEP, Apollo 15, ATM 926, 25 November 1970.

3.0 DISCUSSION

The Approach in this analysis is as follows:

1. Define LR^3 mission functions to be performed.
2. Define hardware elements performing each function.
3. Define the ways in which these hardware elements may fail to perform, the effect on experiment success, and the probability of such failure occurring.
4. Select those items from (3) which have significant effect on experiment success plus significant probability of occurring. These items may then be the basis for reliability improvement recommendations.

3.1 Mission Functions and Associated Hardware

Figure 1 summarizes the major functions to be performed in connection with LRRR from launch through 10 years on the lunar surface. Table I summarizes the significant failure modes within the experiment and is referenced to Figure 1 through the symbols assigned to the blocks. Where applicable, Table I specifies the hardware element, or elements, associated with a specified mission function.

3.2 Failure Modes and Effects Summary

3.2.1 In Table I, under both the Seriousness and Probability of Occurrence columns, only three entries appear--Negligible, Significant, and Unknown. This approach has been taken under the following rationale: The usual approach would be to assign a numerical rating to both Seriousness and Probability of Occurrence, then to multiply one by the other to arrive at a measure of criticality. These criticality rankings would than be ordered and corrective action applied in accordance with the ordered criticality. With this type of approach, considerable effort is expended on the assignment of numbers to items which have little chance of requiring corrective action. In effect, the decision on where corrective action will be applied is delayed until all items are ranked and even then there is the question of how critical an item must be ranked in order to receive attention. The negligible vs. significant approach requires a decision on an as-you-go basis. To label something negligible states immediately that nothing further will be done on the item. To label it significant (both on seriousness and probability of occurrence) identifies that an attempt must be made to upgrade the reliability of this item.

3.2.2 The column labeled "Detectable During" is used to indicate those tasks within the program which can add to (or subtract from) confidence in the experiment reliability. Therefore both analysis and test are included where applicable.

4.0 RESULTS AND CONCLUSIONS

4.1 The results of the analysis are summarized in Table I. Because of the structural nature of the hardware and its inherent tolerance to predictable mechanical stresses, Table I does not include entries pertaining to the pre-landed environments. In addition, analysis relating blocks Q and R, see

Figure 1, is omitted since this hardware is essentially identical to that which is currently operational on the lunar surface. The failure modes and effects of blocks D through P are tabulated in Table I. Of these, only M_2 requires further investigation. Design, construction, and rigorous crew training should affirm that the gnomen will not bend or break during normal handling and deployment.

4.2 Array tipping was called out as a significant occurrence in Apollo 14 but it is not considered as such on Apollo 15. The angle of tipover onto the undeployed Panel B is 22° and the angle of tipover onto the undeployed leg assembly is 18°.

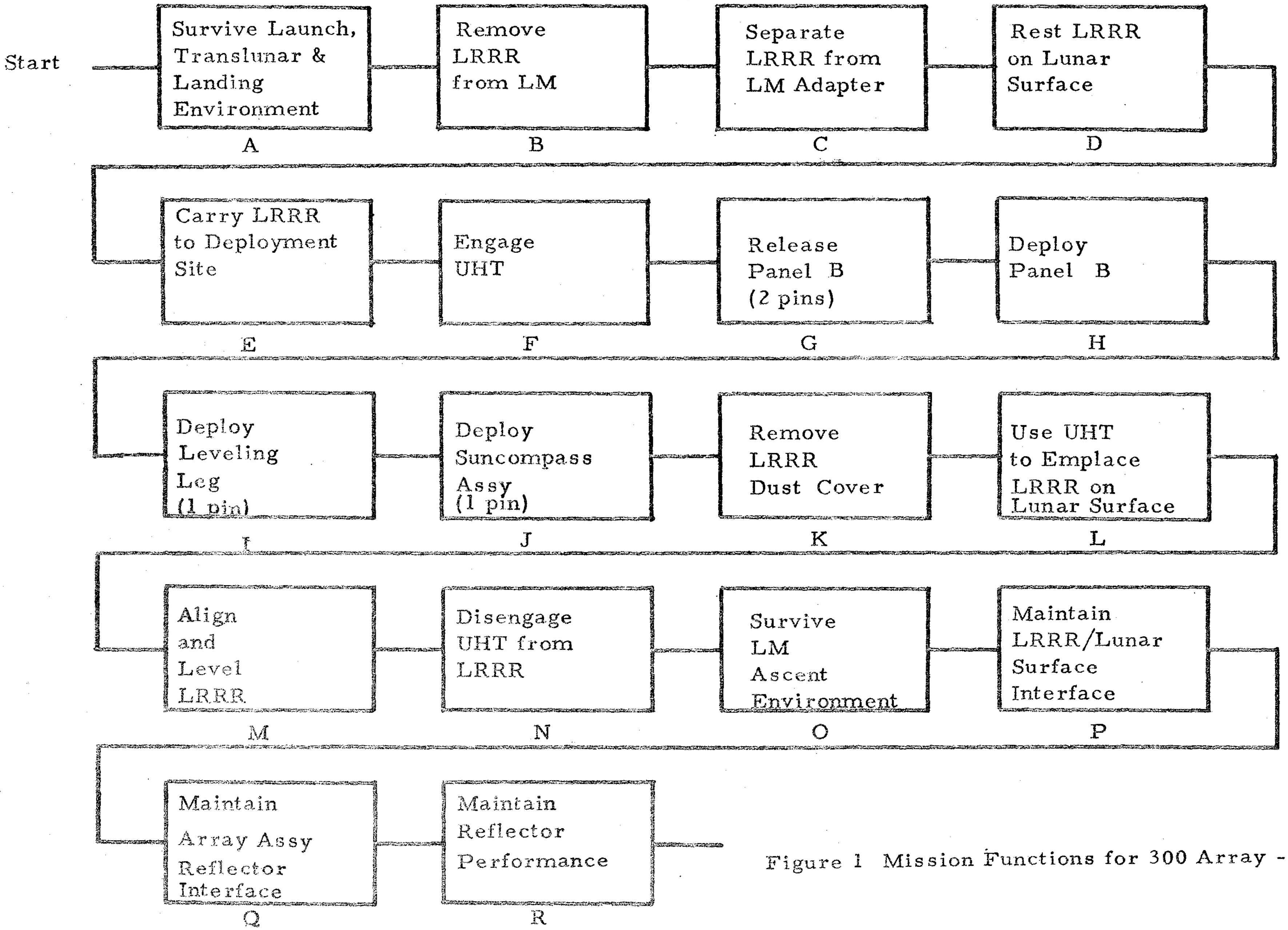

Figure 1 Mission Functions for 300 Array - LRRR

TABLE 1

SUMMARY OF LRRR FAILURE MODES AND EFFECTS

Mission Function	Sym.*	Hardware	Statement of Assumed Failure	Seriousness	Probability of Occurrence	Detectable During	Remarks
Rest LRRR on Lunar Surface	D_1	Back Rest Assembly	Tip over onto Array Face	1. Significant. 2. Critical if Dust Cover is accidentally removed.	Negligible	Crew Training	Astronaut should partially imbed back rest assembly in lunar surface to prevent LRRR from tipping over. In the event LRRR tips over to Array, Astronaut must use handle end of UHT to retrieve experiment.
	D_2		Tipover onto undeployed leveling leg	Negligible	Negligible	Crew Training	Astronaut must use handle end of UHT to retrieve experiment.
Carry LRRR to Deployment Site	E	Handle	None Assumed	N/A	N/A	N/A	None.

*Block Designation From Figure 1.

TABLE 1 (CONT.)

Mission Function	Sym.*	Hardware	Statement of Assumed Failure	Seriousness	Probability of Occurrence	Detectable During	Remarks
Engage UHT	F	UHT/UHT Socket Interface	Failure of Tool to Engage socket	Significant	Negligible	Functional Tests	None.
Release Panel (2 Pins)	G	Pull Pins (2)	Either one or both Remain Stuck	Significant	Negligible	Functional Tests	None.
Deploy Panel	H_1	Hinges (2)	Hinges Fracture (Either one or Both)	Significant	Negligible	Functional Tests	Provide Adequate Margin of Safety.
	H_2	Latch/ Lock Assys (2)	Fails to Lock	Significant	Negligible	Functional Tests	None.
Deploy Leveling Leg (1 Pin)	I	Pull Pin	Stuck Pin	Significant	Negligible	Functional Tests	In event leg will not deploy, astronaut could use lunar surface material to back up array to desired tilt angle.

TABLE 1 (CONT.)

Mission Function	Sym. *	Hardware	Statement of Assumed Failure	Seriousness	Probability of Occurrence	Detectable During	Remarks
Deploy Leveling Leg (1 Pin)	I	Latching Mechanism	Spring Failure	Significant	Negligible	Functional Tests	In the event of spring failure in latching mechanism, astronaut should use lunar soil or lunar rock and bubble level to deploy LRRR. Has a positive lock which is not subject to after-deployment failure.
Deploy Sun Compass Assembly	J_1	Pull Pin (1)	Stuck Pin	Significant	Negligible	Functional Tests	None.
	J_2	Springs (2)	Break or Loss of Tension	Negligible	Negligible	Functional Tests	Astronaut can deploy manually.
Remove LRRR Dust Cover	K	Lanyard	Broken Lanyard	Significant	Negligible	Crew Training	If lanyard breaks, astronaut should attempt to manually remove Dust Cover using UHT. Inability

TABLE 1 (CONT.)

Mission Function	Sym.*	Hardware	Statement of Assumed Failure	Seriousness	Probability of Occurrence	Detectable During	Remarks
Remove LRRR Dust Cover (Continued)							to remove Dust Cover would result in degradation of scientific data.
Use UHT to Emplace LRRR on Lunar Surface	L	UHT/UHT Socket Interface	Failure of Tool to Engage Socket	Significant	Negligible	Functional Tests	If astronaut still is unable to engage UHT into socket, he should insert handle of UHT into handle of experiment.
Align & Level LRRR	M_1	UHT/UHT Socket Interface	Fracture of Tool and/or Socket at Interface	Significant	Negligible	Crew Training	Allow adequate margin of safety. Astronaut can manually align LRRR using opposite end of UHT or boot.

TABLE 1 (CONT.)

Mission Function	Sym. *	Hardware	Statement of Assumed Failure	Seriousness	Probability of Occurrence	Detectable During	Remarks
Align & Level LRRR	M_2	Gnomen/ Sun Compass	Bent Gnomen	Significant	Significant	Functional Tests	Allow Adequate margin of safety. Return signal to Earth has tolerance of 4 miles.
	M_3	Bubble Level	Unreadable	Significant	Negligible (Note 1)	Lunar Deployment	Astronaut can construct and use local vertical reference.
Disengage UHT from LRRR	N	UHT/UHT Socket Interface	Failure of Tool to Disengage from Socket	Significant	Negligible	Crew Training	None.
Survive LM Ascent Environment	O	Complete Array Assembly.	Contamination of retro reflector with lunar debris.	Significant	Negligible	Acquisition of signal by ground observatory	Follow deployment procedures. Make sure all man-made debris near experiments is not free to move.

NOTE 1 - Identical Level Survived Apollo 11 Mission.

TABLE 1 (CONT.)

Mission Function	Sym. *	Hardware	Statement of Assumed Failure	Seriousness	Probability of Occurrence	Detectable During	Remarks
Maintain LRRR / Lunar Surface Interface	P	Complete Array Assembly	Assembly is dislocated by lunar environment or other unknown.	Negligible	Negligible	Lunar Operation	None.